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Pressure Influence of some Residual Gases on the Sputtering Rate of Si

Wpływ ciśnienia resztkowych gazów na szybkość rozpylania krzemu

Влияние давления остаточных газов на скорость распыления кремния

The investigation of electrical properties of implanted semiconductors, as well as the measurements of the range distribution of impurities into semiconductors, introduced by diffusion or implanation, demand a removing thin layers from the investigated materials. For this purpose the sputtering phenomena are used more and more frequently [1, 2, 3, 4]. In this method, the main role is the knowledge of the etching rate of layers from the sample during sputtering. The influence of pressure on the sputtering rate was found by Wehner and Almen [5, 6, 7]. The authors suggested that, the nature of the sample surface has the essential influence on sputtering rate.

The measurements of the sputtering rate for the mono-crystalline — Si as a function of pressure and residual gas are presented in this work. The experiments are performed by means of an apparatus given in reference [8]. The samples are sputtered by Ar^+ of 500 eV energy and 0.25 mA/cm^2 current density. An ion source of Kaufmann type [10] was used in the measurements. The base pressure in the collector chamber was 7×10^{-7} mmHg and increased to 6×10^{-5} mmHg during gas dosing into the ion source. The measurements were carried out after heating the ion source for one hour. The time of sputtering was 30 minutes. A part of each sample was covered by thin Al layer. After sputtering Al mask was removed and the step thus obtained was measured by

means of interference microscope. This enabled us to obtain the etching rate of the sample. The measurements of the sputtering ratio as a function of pressure were carried out. For this purpose the various kinds of gases were introduced into the collector chamber by the gas inlet system.

The sputtering ratio of Si was investigated in the presence of argon, helium, nitrogen, carbon, dioxide and air atmospheres. The results are compared with the sputtering rate without additional gases and presented in Fig. 1 (x_0 is the sputtered layer without any gas dosing into the collector chamber).

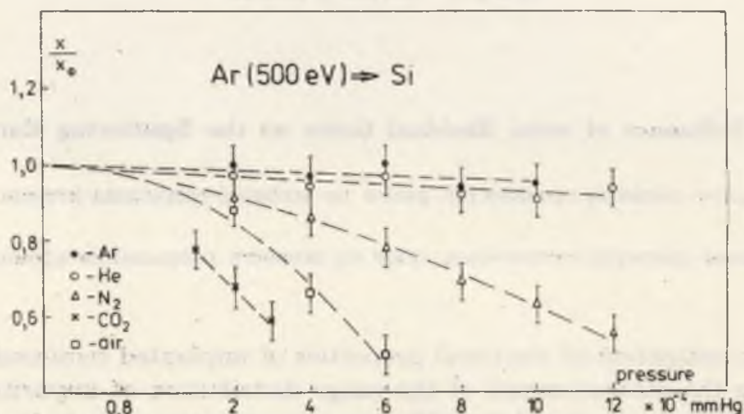

Fig. 1. A relative change of the sputtering ratio as a function of gas pressure in the collector chamber

As shown in Fig. 1 the sputtering rate is independent of pressure (in the investigated range) when argon or helium gases are introduced into the collector chamber. Moreover, in case of presence of nitrogen, carbon dioxide and air it was found that the sputtering ratio is dependent on pressure. The sputtering of the samples in N_2 atmosphere decreases the sputtering ratio by 40% where the pressure reaches 1.2×10^{-3} mmHg, while it decreases by the same ration at pressure 3.2×10^{-4} mmHg of CO_2. In case of air the sputtering rate decrease by 50% at pressure 6×10^{-4} mmHg. The lack of dependence of the sputtering rate of Si on pressure in case of Ar and He, can be elucidated by a very weak adsorption of inert gas. In case the process of adsorption does not influence the sputtering rate, the following formula must be fulfilled:

$$n_2 \gg n_1 \tag{1}$$

where:

n_2 — is the number of the sputtered atoms from 1 cm² per 1 sec.,
n_1 — is the number of the absorbed atoms.

The value of n_1, can be determined from the formula [9]:

$$n_1 = 3.5 \times 10^{22}\, p \cdot f / \sqrt{M_o T} \quad (2)$$

where:

p — is the gas pressure,
M_o — is the molecular mass of the gas,
T — surface temperature,
f — adsorption coefficient.

A decrease in the sputtering rate of Si crystal with an increase of N_2, CO_2 and air pressure into the chamber may be due to a high adsorption of these gases on the sample surface. Such a decrease in the sputtering ratio can also be due to the layers of carbon and Si-oxide produced on the sample surface during sputtering process.

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STRESZCZENIE

W pracy przedstawiono wyniki pomiarów szybkości rozpylania monokrystalicznego krzemu w zależności od ciśnienia i rodzaju gazów w aparaturze do rozpylania, opisanej w pracy [8]. Badano szybkość rozpylania krzemu w atmosferze argonu, helu, azotu, dwutlenku węgla i powietrza, jonami Ar^+ o energii 500 eV i przy gęstości prądu 0,25 mA/cm^2.

Otrzymane wyniki wskazują, że atmosfera gazów szlachetnych Ar, He nie oddziałuje na szybkość rozpylania Si, natomiast atmosfera azotu, CO_2 i powietrza ma znaczny wpływ na szybkość rozpylania, a mianowicie: przy dozowaniu azotem szybkość rozpylania zmniejsza się o 40% przy ciśnieniu $p=1{,}2\times10^{-3}$ mmHg, dla

CO_2 takie samo obniżenie szybkości rozpylania obserwuje się już przy ciśnieniu 3×10^{-4} mmHg, a dla powietrza obniżenie o 50% występuje przy ciśnieniu 6×10^{-3} mmHg.

РЕЗЮМЕ

В работе представлены результаты исследований скорости распыления монокристаллического кремния в зависимости от давления и типа газа, проведенных на установке описанной в работе [8]. Исследовано скорость распыления кремния в атмосфере аргона, геля, азота, двуокиса углия и воздуха, ионами аргона с энергией 500 eV и плотностью тока 0,25 mA/cm².

Не обнаружено влияния атмосферы инертных газов (Ar, He) на скорость распыления кремния. В случае N_2, CO_2 и воздуха подтвердилась сильная зависимость от типа газа и его давления.

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